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STUDY TO DEVELOP IMPROVED SPACECRAFT SNOW SURVEY METHODS USING SKYLAB/EREP DATA

(EREP Investigation No. 420)

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PURPOSE OF INVESTIGATION

The purpose of this investigation is to compare and evaluate Skylab data for mapping of snow cover. Visual interpretation of the S190 photographs will be performed to map areas that are snow-covered. The S192 imagery and digital printouts, S193 data, and S194 data will then be compared to the S190 photographs to determine how much additional information on areal extent of snow can be obtained from various spectral bands, thermal data, and microwave data. Snow-depth and area measurements taken routinely by various Government agencies in the Sierra Nevada, Cascades, and Great Plains shall provide ground truth. The relatively high-resolution EREP data will be compared with television and radiometric measurements from other satellites, and available aircraft imagery, to determine the optimum future system for mapping the areal extent of snow. The results of this investigation will enable a more accurate assessment of the extent of snow cover in the United States and aid in prediction of run-off and better management of the country's water resources.

ACCOMPLISHMENTS DURING REPORTING PERIOD

a) SL-2 Imagery

During this reporting period additional data from the SL-2 mission were received. These data include three rolls of interim S192 film (data product S055-1) for Test Site 318107 (EREP Pass 3, 3 June 1973). The film contains two segments of the flight, covering the White Mountains on the California-Nevada border. For one segment useful imagery for spectral Bands 3, 9, and 11 is contained on the film; data for Bands 8 and 10 are also on the film, but are too dark to be of use. For the other segment, the film contains useful data for Bands 3, 9, and 11, and marginally useful data for Band 7 (the image is very light for this band); the data for Bands 8 and 10 are too dark and that for Bands 4 and 6 too light to be of use.

Examination of the interim film reveals variations in the reflectance of snow-covered areas that are in accordance with those observed in the initial S192 screening film. In Bands 3 (0.52-0.56 μm) and 7 (0.78-0.88), the snow surface appears bright; no significant change in the reflectance of the snow is detectable when comparing these two spectral bands. In

the Band 9 imagery, however, the extent of the snow-covered area that has a high reflectance is considerably less than in the two shorter wavelength bands (Band 9 is 1.09-1.19 μm). In fact, it appears that only the snow at the higher elevations of the White Mountains has a high reflectance; the snow at lower elevations cannot be detected in this band. In Band 11 (1.55-1.75), a complete reversal in reflectance is seen, with the snow actually appearing darker in tone than the surrounding terrain.

In the area covered by these film segments, some cellular clouds also exist. Whereas the snow reflectance changes from band to band, however, no significant change in the cloud reflectance is seen over the spectral range of these four bands. Thus, through a comparison of two or more of the S192 spectral bands, it appears that it may be possible to develop a technique to distinguish snow from clouds. And, as stated in earlier progress reports, the variations in the snow reflectance may be related to the snow surface condition, with the reflectance dropping more sharply for wet snow surfaces. Further analysis of these film segments is in progress to determine more precisely the magnitude of the reflectance variations.

b) SL-2 Computer Tapes

Two additional computer tapes were received during this reporting period. One tape contains S193A data (product S061-1) for Test Site 318108, EREP Pass 8 (11 June). The other tape contains S191 data (product S041-1), but appears to be from the SL-3 mission, EREP Pass 14 (5 August); since very little snow exists in August, it is doubtful that these data will be of any use.

The S192 tape received earlier is annotated as being for the same segment of Test Site 318107 as is covered in the interim film discussed above. The EREP Data Acquisition Status Report for the SL-2 mission (Revision A, 14 September 73) indicates that for this particular flight segment the S192 instrument was marginally aligned without attenuator for Bands 1-12 and not aligned for Band 13. Therefore, the data could only be expected to be of marginal use at best. Nevertheless, this tape was processed; however, because of the difficulties explained in the following paragraphs, it was not possible to obtain useful quantitative data from the tape. The

characteristics of the data output are as follows:

1. the data are in digital count form (0-255 counts per channel) in 22 tape channels. Two channels contain zeroes.

2. Digital-to-radiance conversion factors are provided for channels 1-14 and 17-22. It is assumed, therefore, that the two empty channels are the Band 13 high sampling channels 15 and 16. Band-to-channel identification was made counting channels across from 1-14 and 17-22 and using Table 5-1 of TR-524 (Revision A).

3. The following features are noted:
   a) There is a considerable amount of scene saturation (0 and 255 data points);
   b) Band 13 (low sampling rate) - Channel 21 is almost completely saturated;
   c) There seems to be no consistent recognizable correlation between the counts in the odd and even components of the channels sampled at the high rates. This is disturbing and not understood.
   d) Scan arc pixel latitude and longitude designations appear to be incorrect, although the spacecraft nadir coordinates are correct.
   e) Consistent features do not appear to correlate from band-to-band along the scan line.

c) SL-3 Mission Support

Mission support was provided throughout the period of the SL-4 mission. Because of lighting conditions, the data-take with regard to this experiment was anticipated to take place during the last third of the mission, after January first. This was opportune because adequate snow cover conditions existed in all test sites, even the non-mountain test site in the north-central United States, during the month of January. In general, the western half of the United States had received substantial snowfalls in late December and early January; a gradual melting trend then occurred in most areas during the rest of the month.

The collection of ground-truth data by other agencies was coordinated. For the Salt-Verde watershed in central Arizona, an aerial-survey flight was made on 15 January; the resulting data should provide excellent ground-truth for the data collected over this test site on EREP Pass 83, on 14 January.

d) SL-4 Data

1. Data Books

Several data books for the SL-4 mission have been received. These include four S190A books (Product S022-1) for EREP Passes 83, 89, 90, and 98, two S190B books (Product S032-1) for Passes 89 and 98, and five S192 books (Product S052-7) for Passes 83, 89, 90, and 98. The test sites and dates of the data-takes are as follows: EREP Pass 83, 14 January, Sites 318208 and 318592; EREP Pass 89, 24 January, Site 318592; EREP Pass 90, 25 January, Site 318592; and EREP Pass 98, 1 February, Site 318107.

2. S192 Screening Film

For the EREP passes listed above, S192 screening film has been received. For Pass 83, the film contains Bands 2, 7, and 11, and for Passes 89, 90, and 98, the film contains Bands 6, 9, and 13-1. This film is being examined to select the segments for which the final data product will be ordered. The initial examination of the film indicates well-defined snow patterns in the shorter wavelength bands; the Band 11 imagery is very dark, and patterns are difficult to distinguish in some parts of the thermal infrared film.

3. Aircraft Support Data

Film from two aircraft support flights has been received. One flight covered a part of Test Site 318107, the southern Sierra Nevada, on 28 January; the other flight covered the western part of Test Site 318208, the Salt-Verde Watershed, on 15 January. The aircraft data consist of S0397 color film from an RC-8 camera for both flights, and 2479 thermal IR film (10.2-12.5 μm) from an RS-7 sensor for the southern Sierra Nevada flight. The initial review of the film indicates that the data are of very good quality, and should provide excellent ground-truth for the Skylab data collected over

these test sites on EREP Passes 98 (1 February) and 83 (14 January), respectively.

TRAVEL SUMMARY

Mr. James Barnes, the Principal Investigator, visited Johnson Space Center in early March to participate in the crew debriefing for the SL-4 Visual Observations Project. During the visit Mr. Barnes met with the Contract Technical Monitor to discuss the status of the EREP sensors, the schedule for processing of the data, and the progress of the investigation to date.

PLANS FOR THE NEXT REPORTING PERIOD

During the next reporting period, the analysis of the photographic data products for the SL-2 mission will be continued. The snow extent and other snow characteristics mapped from the S190A and B products will be compared with the patterns mapped from ERTS imagery and with other ground truth data. It is anticipated that some of the S190A and B products from the SL-4 mission will also become available during the next reporting period; if these photographs are received, the wintertime snow patterns can be compared with the patterns from the late spring of the previous season. The handheld camera photographs from the SL-4 mission have already been received for study in the Visual Observations Project.

Further analysis will be carried out using the S192 interim film from the SL-2 mission and the S192 screening film from the SL-4 mission. The snow extent visible in the various spectral bands will be carefully mapped to determine more precisely the magnitude of the band-to-band variations. Although it is recognized that the SL-4 screening film is of relatively poor quality, it is hoped that the film will be of some use for comparing the reflectance variations during winter with those observed in the film from the SL-2 mission; such a comparison might provide an indication of the effects of different snow conditions on the observed reflectance, since the winter snow would presumably be cold and dry, whereas the late spring snow would be in a melting condition.

Further processing of the SL-2 taped data products is not planned for the near future, because of our understanding that much of the early data contains errors and our experience with the one S192 tape that we have worked with. We plan to contact the appropriate personnel at JSC who are familiar with each sensor system to determine the exact status of the data and the best course to follow with regard to processing the tapes.

SUMMARY OUTLOOK

Based on the information received to date, it appears that a considerable amount of useful data were collected during the latter part of the SL-4 mission. We believe that these data, together with that from the earlier SL-2 mission, will form a total sample sufficient to enable the objectives of the study to be met successfully.

FINANCIAL REPORT

In accordance with Appendix A of the Work Statement of the subject contract, the Financial Management Report is being submitted as a separate document.

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DISCUSSION OF SIGNIFICANT RESULTS

A segment of the interim S192 film product (Product S055-1) from the SL-2 mission has been examined. The film, which is from EREP Pass 3, covers the White Mountains area near the California-Nevada border. The corresponding S190A photography for this pass shows that snow cover still exists in the White Mountains at that time, 3 June 1973. The S190A photography also shows considerable cellular-type cloudiness in the area.

The film contains useable data for the following S192 spectral bands: Band 3 (0.52-0.56 μm), Band 7 (0.78-0.88 μm), Band 9 (1.01-1.19 μm), and Band 11 (1.55-1.75 μm). Examination of the film reveals variations in the reflectance of the snow surface that are in accordance with those observed in the initial S192 screening film (reported in an earlier Progress Report.) In Bands 3 and 7, the snow appears very bright, with no discernible difference when comparing these two spectral bands. In the Band 9 imagery, however, the extent of the snow-covered area that has a high reflectance is considerably less than in the two shorter wavelength bands. In fact, it appears that only the snow at the higher elevations of the White Mountains has a high reflectance; the snow at lower elevations cannot be detected in this band. In Band 11, a complete reversal in reflectance is seen, with the entire snow-covered area actually appearing darker in tone than the surrounding terrain.

Whereas the snow surface exhibits wide variations in reflectance, no significant change in the reflectance of the clouds occurs over the spectral range of these four bands. In the Band 11 data, therefore, the clouds

appear white and snow appears black; in the Band 3 data, both the clouds and the snow appear white.

Two potential applications are possible, based on these results. First, because the reflectance of the snow surface in the Band 9 data is much lower at the lower elevation terrain of the White Mountains, it appears that the drop in reflectance in the near-IR portion of the spectrum may be related to the wetness of the snow surface. In early June, the snow would be expected to be melting at the lower elevations, but might still be dry at the highest elevations. Thus, measurements at this spectral band (1.09-1.19 μm) may have application for distinguishing between dry and melting snow surfaces.

Secondly, the complete reversal in reflectance that is observed in the Band 11 data (1.55 - 1.75 μm) indicates that in this portion of the spectrum snow surfaces have a low reflectance regardless of the condition of the snow. Because clouds do not exhibit a similar drop in reflectance, measurements in this spectral band have potential use for automatically distinguishing snow from clouds. In a scene using two spectral bands, say Band 3 (visible range) and Band 11, features that have a high reflectance in both bands would be clouds, features that have a high reflectance in the visible but a low reflectance in the near-IR would be snow, and features that have a low reflectance in both bands would be cloud-free terrain that is not snow covered.